Source Waterbody Physical Data
Callaway Energy Center

Submitted in Compliance with
Section 316(b) Rule
40 CFR 122.21(r)(2)

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List of Abbreviations and Acronyms

AMSL	above mean sea level
AOI	area of influence
BTA	best technology available
CEC	Callaway Energy Center
cfs	cubic feet per second
CWIS	cooling water intake structure
DIF	design intake flow
DO	dissolved oxygen
ft	foot/feet
FNU	formazin nephelometric unit
fps	feet per second
gpm	gallons per minute
IM&E	impingement and entrainment
LWL	low water level
µS/cm	microsiemens per centimeter
MDNR	Missouri Department of Natural Resources
mg/L	milligram per liter
MGD	million gallons per day
mi	mile(s)
MWIS	makeup water intake structure
NGVD	National Geodetic Vertical Datum (of 1929)
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NWL	normal water level
RM	river mile
sq mi	square mile(s)
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USNRC	U.S. Nuclear Regulatory Agency

1.0 Introduction

In accordance with Section 316(b) of the Clean Water Act, the U.S. Environmental Protection Agency (USEPA) has promulgated rules under 40 CFR Part 125, Subpart J (the Rule) that require the determination of best technology available (BTA) to reduce mortality associated with the impingement and entrainment (IM&E) of aquatic biota. Section 40 CFR §122.21(r)(2) requires the owner or operator of a facility with a cooling water intake structure (CWIS) to submit source water physical data with an application for a National Pollutant Discharge Elimination System (NPDES) permit. Source water physical data are required regardless of the compliance alternative selected to demonstrate BTA.

The required data are used by the Director (i.e., permitting authority) to characterize the facility and evaluate the type of waterbody potentially affected by the CWIS. This includes local species potentially impinged and entrained by the facility's CWIS. Additionally, the information provided is relevant in supporting the reasonableness of the proposed design, construction technologies, operational measures, and restoration actions of the facility for meeting the requirements of the Rule.

Under 40 CFR §122.21(r)(2), specific information that must be submitted for the facility includes:

> *(i) A narrative description and scaled drawings showing the physical configuration of all source water bodies used by your facility, including areal dimensions, depths, salinity and temperature regimes, and other documentation that supports your determination of the water body type where each cooling water intake structure is located;*
>
> *(ii) Identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods you used to conduct any physical studies to determine your intake's area of influence within the waterbody and the results of such studies; and*
>
> *(iii) Locational maps.*

The following sections present the information required pursuant to 40 CFR §122.21(r)(2) for the Callaway Energy Center (CEC). It should be noted that CEC refers to its CWIS as a makeup water intake structure (MWIS). This report will use the term MWIS, but it is understood that the two phrases have the same meaning.

1.1 Overview of the Callaway Energy Center

CEC is a baseload, single-unit nuclear generating facility located approximately 10 miles southeast of Fulton, Missouri in Callaway County approximately five miles north of the Missouri River (Figure 1-1). CEC draws makeup water for its closed-cycle cooling water system at its shoreline MWIS at river mile (RM) 115.4 (Figure 1-2). CEC consists of a pressurized water reactor, four steam generators, one steam turbine generator, and a closed-cycle heat dissipation system. The heat dissipation system consists of a 555 foot (ft) high hyperbolic natural draft cooling tower; the MWIS; a main condenser; and a cooling tower basin and blowdown discharge pipeline. The system recirculates 530,000 gallons per minute (gpm) of water through the natural draft tower to remove waste heat during normal operations.

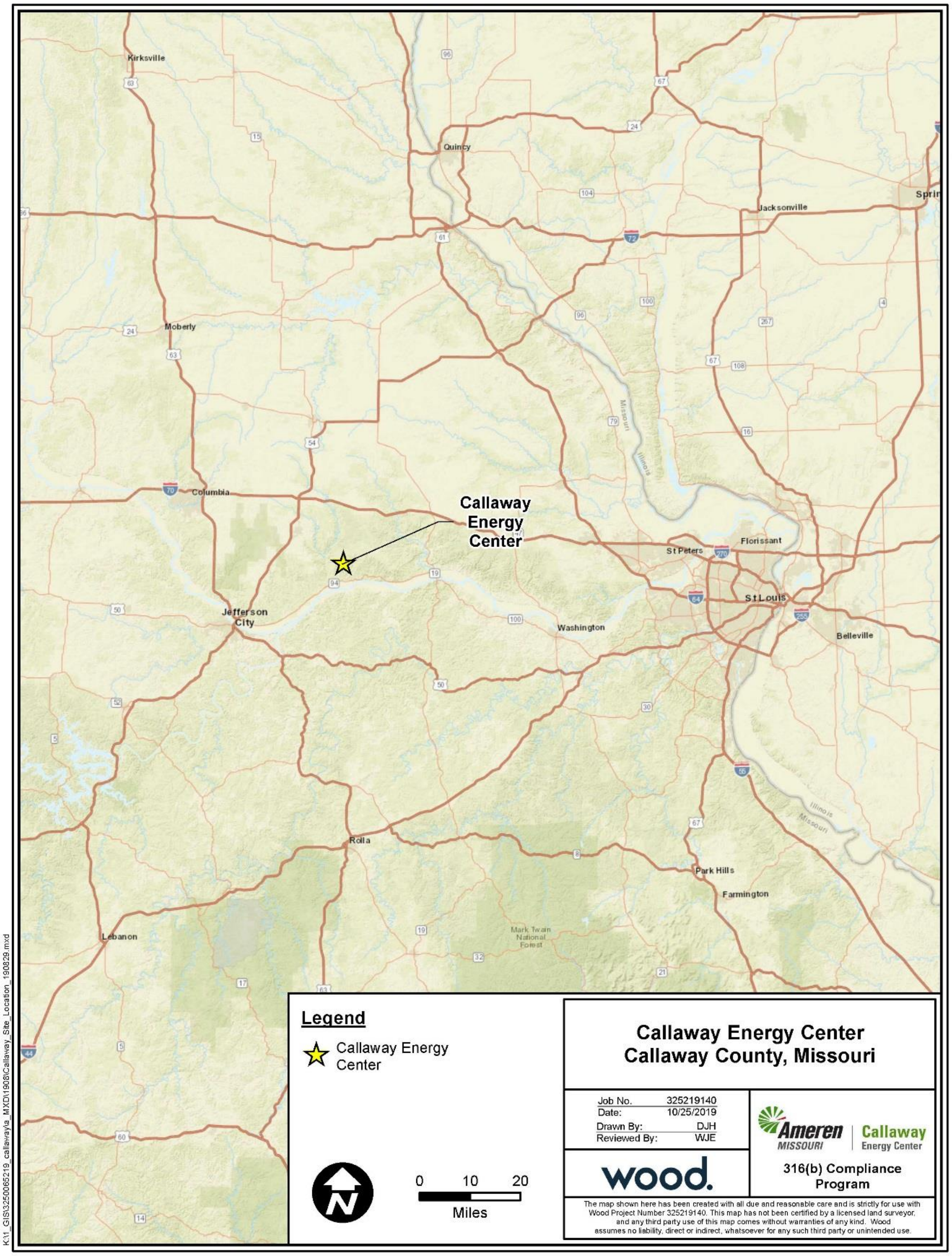

Figure 1-1. Location of the Callaway Energy Center

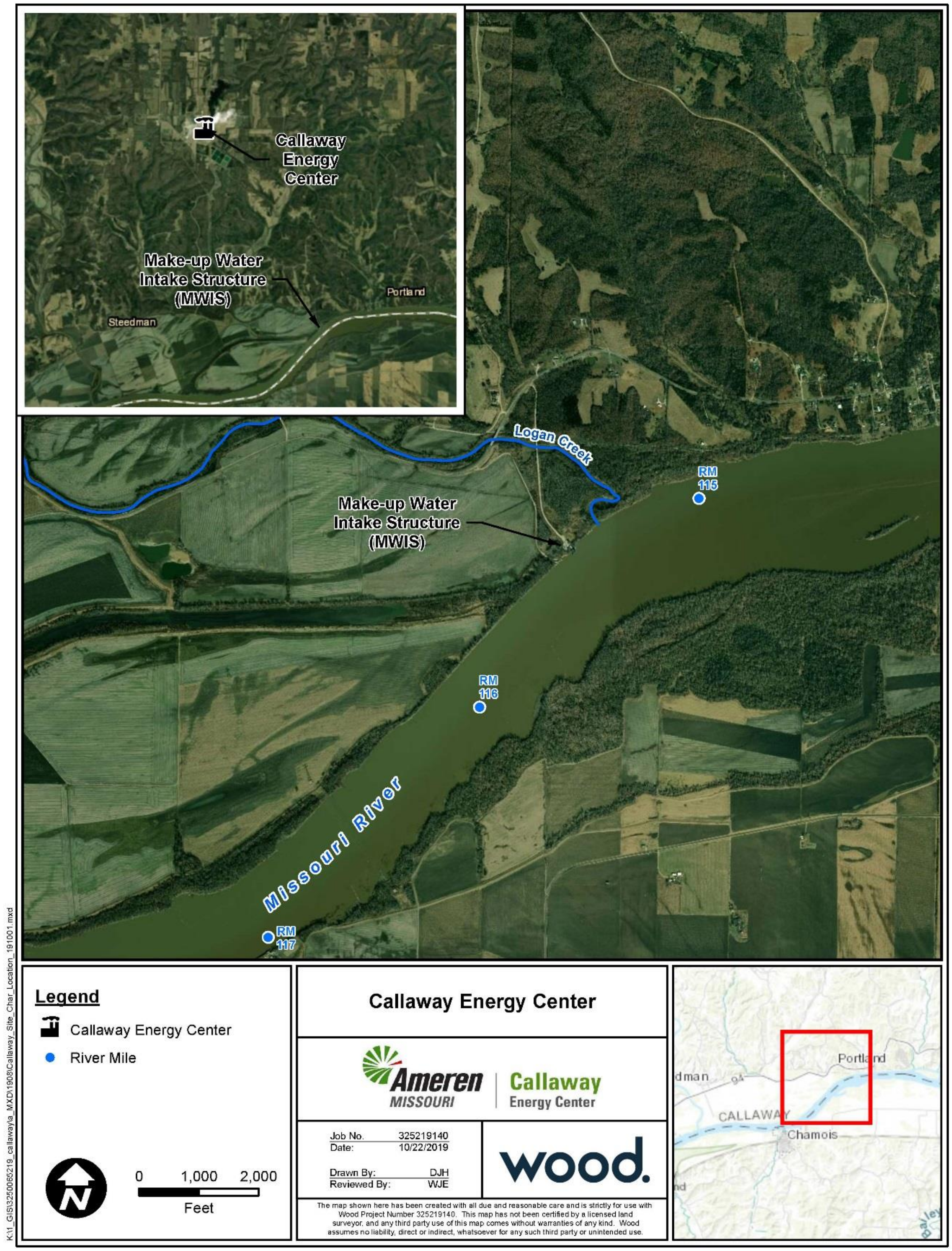

Figure 1-2. Location of the Callaway Energy Center Makeup Water Intake Structure

2.0 Physical Configuration of The Source Waterbody

2.1 Habitat and Morphology Features

Physical characteristics of the source waterbody provide the Director with supporting information to define the quality and quantity of aquatic habitat in the vicinity of the MWIS. Physical features include: water depth, shoreline and channel morphology, the availability and type of potential spawning and nursery habitat, and water quality characteristics. Table 2-1 presents a summary of the physical characteristics of the source waterbody including its configuration in the vicinity (i.e., 1-mile [mi] radius) of the MWIS.

The coordinates for CEC's Missouri River MWIS are:

Latitude	Longitude
38°42'12"	91°44'18"

The Missouri River Basin drains an area of 529,350 square miles (sq mi) and is the largest river basin in the United States (USACE 2012). The river originates with the confluence of the Gallatin, Madison, and Jefferson rivers near Three Forks, Montana and flows for 2,341 miles south and east to its confluence with the Mississippi River at St. Louis, Missouri. The river passes through seven states including Montana, North and South Dakota, Iowa, Nebraska, Kansas, and Missouri. Geology of the basin is varied from Northern Rocky Mountains at the headwaters, through the glaciated Great Plains and Central Lowlands, and finally through the unglaciated, limestone-dolomite Ozark Plateaus at CEC (Galat et al. 2005a, 2005b). Most of the basin flows through the semi-arid Great Plains and is largely a dryland river. The lower Missouri River and its floodplain from Glasgow, Missouri to St. Louis are largely confined by nearly vertical limestone and dolomite bluffs of the Ozarks.

Upstream dam construction and mainstem channelization of the Missouri River has fragmented the river into four ecological units: a free-flowing reach upstream of the reservoirs, the reservoirs, remnant floodplains between the reservoirs, and a channelized reach below the most downstream reservoir (NRC 2002). Prior to alteration, the hydrology of the river formed a braided, meandering channel with a wide floodplain. High sediment loads were the norm due to seasonal rains and the highly erodible soils of the basin. However, conditions on the Missouri River have changed dramatically over the past century as a result of navigation and flood control. Modifications began in the late 1800s with removal of snags to permit navigation, followed by channel enhancements in the early 1900s, and flow regulation via dams in the 1930s (NRC 2002). In the 1950s and 60s, five U.S. Army Corps of Engineers (USACE) dams were built on the mainstem of the upper Missouri River. The lower Missouri River remains unimpounded but has been channelized and has lost connectivity to the floodplain due to levees, bank revetments, and river bar dikes and wing dams (NRC 2011).

Flow in the Missouri River is regulated, as authorized by the Flood Control Act of 1944, according to the Missouri River Main Stem Reservoir System Regulation Manual (USACE 2006). The typical annual flow cycle in the regulated Missouri River involves peak reservoir storage in July, followed by a gradual decline until late winter. There are two natural peak river flows: one in late February to April, created by snowmelt and rainfall in the plains, and a second one in May to July, created by snowmelt and rainfall in the mountains. Targeted flow releases are increased for the navigation period, which normally begins by April 1 near St. Louis and extends until early December. Frequency and severity of floods and droughts have increased over the past few decades. Record floods were recorded in the lower Missouri River in 1993, 2011, and 2019. The increasing trend in flood stage has been attributed to the constriction of the channel by wing dams and levees.

The CEC MWIS is located on an outside bend on the left descending bank within the channelized reach of the lower Missouri River at RM 115.4 (Figure 1-2). The MWIS and the rock revetment slightly protrude from the upstream river bank and the downstream river bank. The main channel of the Missouri River flows directly in front of the MWIS. On the upstream side, there are pipe-pile clusters used to protect the structure from barges. Substrates in the lower Missouri River are mostly sand with small areas of silt and mud (Reuter et al. 2008).

Within a 1-mi radius of the CEC MWIS, the river channel gradually bends, but habitat remains relatively uniform. Under normal river stage, channel width is approximately 1,630 ft. The main channel bends toward the north shore directly in front of the MWIS. Multiple wing dykes along the far shore upstream of the MWIS provide structure and direct flow into the navigation channel. Channel depths are between 18 and 30 ft at normal flows (ASA 2017). The far shore is a shallower, depositional area that has exposed sandbars at low flows. Logan Creek flows into the Missouri River 650 ft directly downstream of the MWIS. A variable riparian zone from 50 to 300 ft wide exists upstream and downstream of the MWIS. A larger, more consistent riparian zone greater than 500 ft wide is established along the far shore. Land use in the area is 40% forest and wetlands, followed by 35% crop land, 18% open water, 6% developed, and 2% herbaceous shrub (USGS 2011).

Table 2-1. Source Waterbody Physical Characteristics Within a 1-mile Radius of the Makeup Water Intake Structure

General Source Waterbody Characteristics	
Source Waterbody Name:	Missouri River
Non-tidal Rivers	
Range of river discharge during the study:	• 34,400 to 492,000 cubic feet per second (cfs) • Mean 112,257 cfs • Median 88,500 cfs
Range of river stage:	• 484 to 517 feet (ft) National Geodetic Vertical Datum (of 1929) (NGVD) • Mean of 494 ft NGVD • Median of 493 ft NGVD
Tidal Rivers/Estuaries	
Tidal variation:	N/A
Salinity ranges:	N/A
Lakes	
Range of the lake stage	N/A
Other	
Other notable changes or activities in the source waterbody that are relevant to impingement & entrainment (IM&E) studies	Missouri River is a navigable river used for commercial transport by barge.
Habitat Characteristics	
Channel Morphology	Channel narrows at “Portland Bend” from river mile (RM) 116 to RM 114.
Aquatic Habitat Features	• Main channel habitat dominates. • Shoreline habitats limited at the makeup water intake structure (MWIS) due to levees and sheet-pile walls. • Multiple wing dykes upstream along the far bank. • Shallower depositional habitat along the far bank and downstream; becomes sandbar habitat at low flows. • Logan Creek confluence 650 ft downstream of MWIS.
Water Depth	Main channel depths range from 18 to 30 ft under normal river stage.
Substrate Type	Dominated by sand.
Shoreline Features	• Immediate vicinity of MWIS is protected by a pipe-pile cluster and sheet-pile wall. • Riparian buffers upstream and downstream.
Width of riparian zone	• 300 ft wide upstream and 50 ft wide immediately downstream of MWIS. • >500 ft wide on opposite shoreline.

2.2 Water Quality Characteristics

Water quality characteristics of the source waterbody are represented by trends in discharge, stage, temperature, pH, dissolved oxygen (DO), conductivity, turbidity, and suspended sediment. These parameters are important indicators of habitat quality and ecosystem function and are used by the Director to estimate the potential impact of the MWIS on the source waterbody. Additionally, temperature and DO are used to interpret trends in IM&E at the MWIS. For example, seasonally depressed temperatures result in greater impingement rates due to increased stress (White et al. 1986; King et al. 2010). Similarly, low DO within the source waterbody may also result in greater impingement rates due to reduced vigor or death of resident fish (King et al. 2010).

Historical data for streamflow and water quality were compiled from the U.S. Geological Survey (USGS) stream gage on the Missouri River at Hermann, Missouri (USGS 06934500). This gage is the nearest to the CEC MWIS and is 17.2 RM downstream. Missouri River discharge and stage data from 2014 through 2019 (5 years) are shown in Figures 2-1 and 2-2. Mean monthly variations in water quality parameters from 2014 to 2019 (5 years for most parameters) are shown in Figures 2-3 through 2-8.

General causes of water quality degradation include sediment, nutrient, and pesticide runoff from agriculture; sediment and metal loadings from mines; urban storm water discharges; wastewater and industrial plant discharges; septic system leaching; and entrapment of sediments and pollutants behind dams. The Missouri River from its mouth at St. Louis to the Gasconade River has designated use support for warmwater fishery, drinking water, recreation, agriculture, industrial, and livestock and wildlife watering (USACE 2006). Portions of the Missouri River are on the Missouri 303(d) List of Impaired Streams due to *Escherichia coli* contamination; however, the section of river around CEC's MWIS is not listed (MDNR 2018).

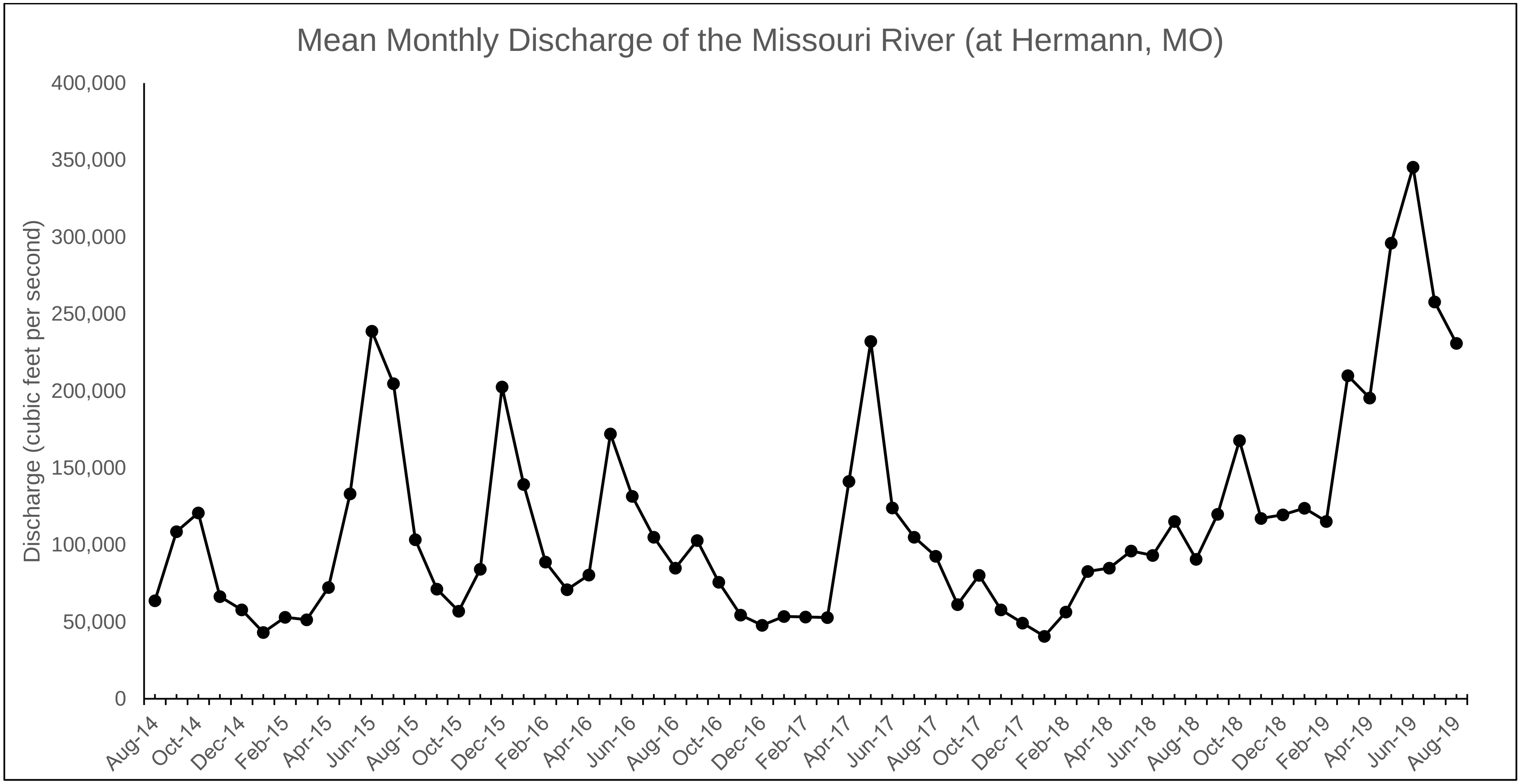

Figure 2-1. Mean Monthly Discharge (cfs) of the Missouri River at Hermann, MO (USGS 06934500) from August 2014 through August 2019

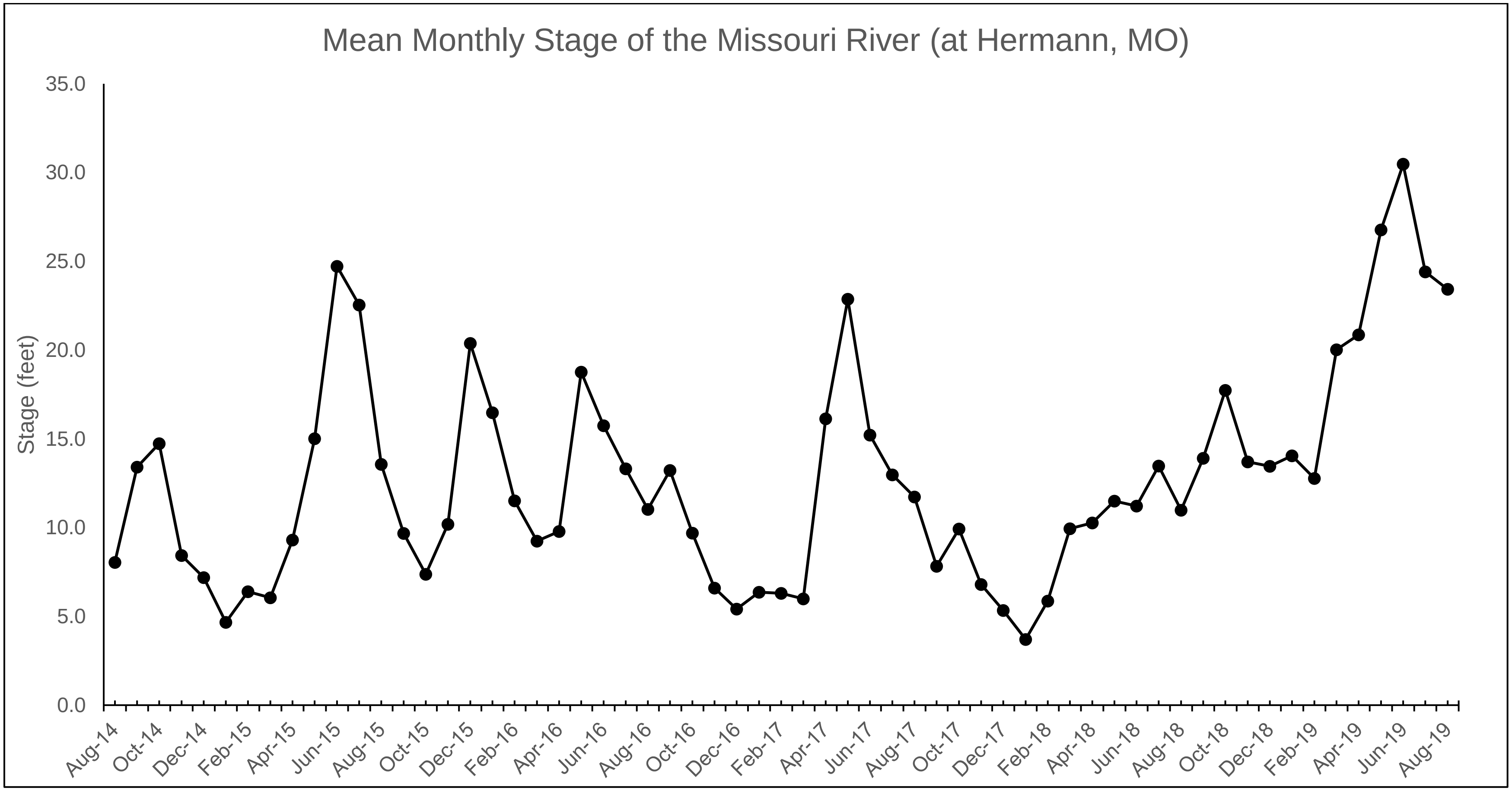

Figure 2-2. Mean Monthly Stage (feet) of the Missouri River at Hermann, MO (USGS 06934500) from August 2014 through August 2019

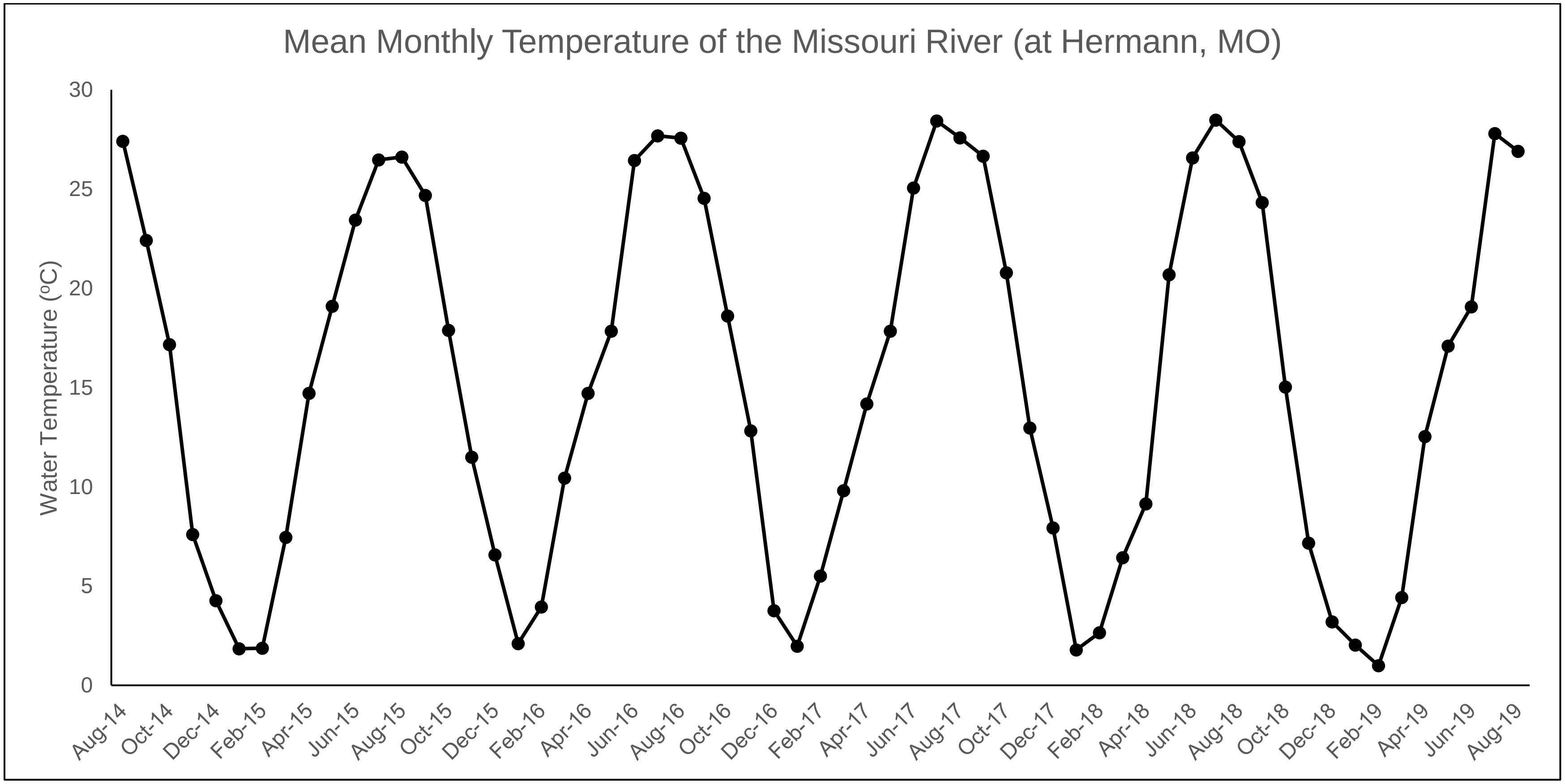

Figure 2-3. Mean Monthly Water Temperature (ºC) of the Missouri River at Hermann, MO (USGS 06934500) from August 2014 through August 2019

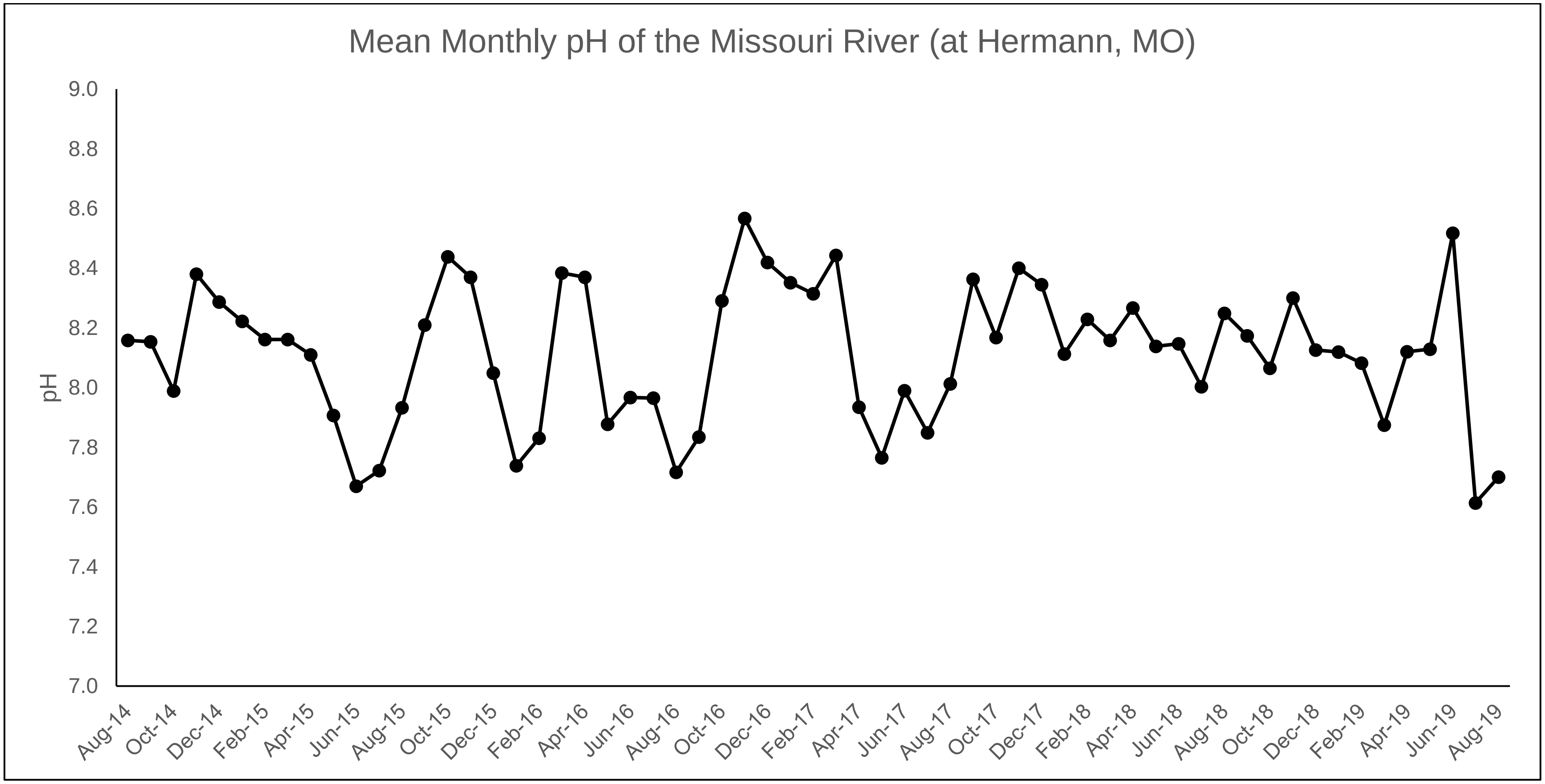

Figure 2-4. Mean Monthly pH of the Missouri River at Hermann, MO (USGS 06934500) from August 2014 through August 2019

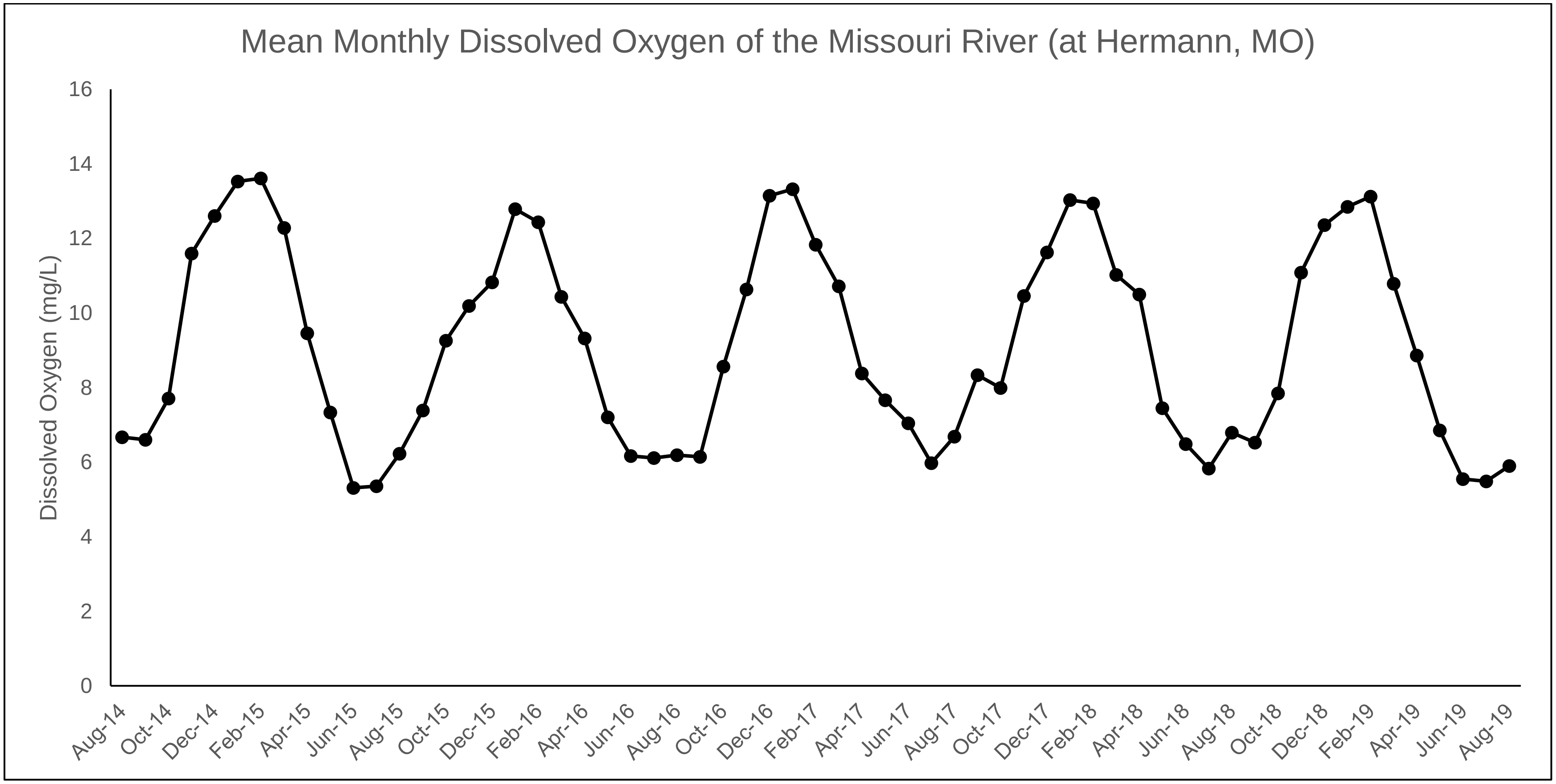

Figure 2-5. Mean Monthly Dissolved Oxygen (mg/L) of the Missouri River at Hermann, MO (USGS 06934500) from August 2014 through August 2019

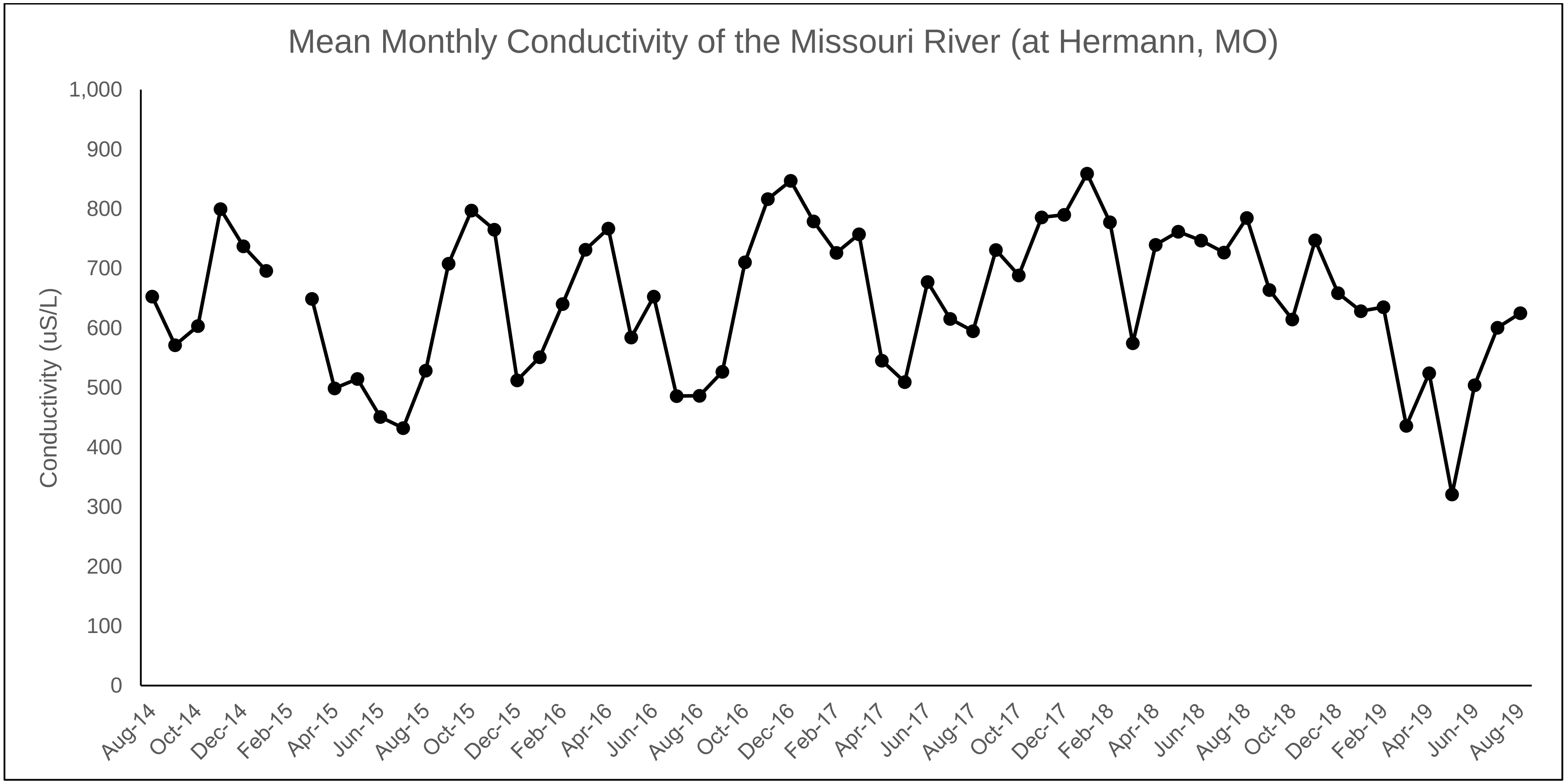

Figure 2-6. Mean Monthly Conductivity (µS/cm) of the Missouri River at Hermann, MO (USGS 06934500) from August 2014 through August 2019

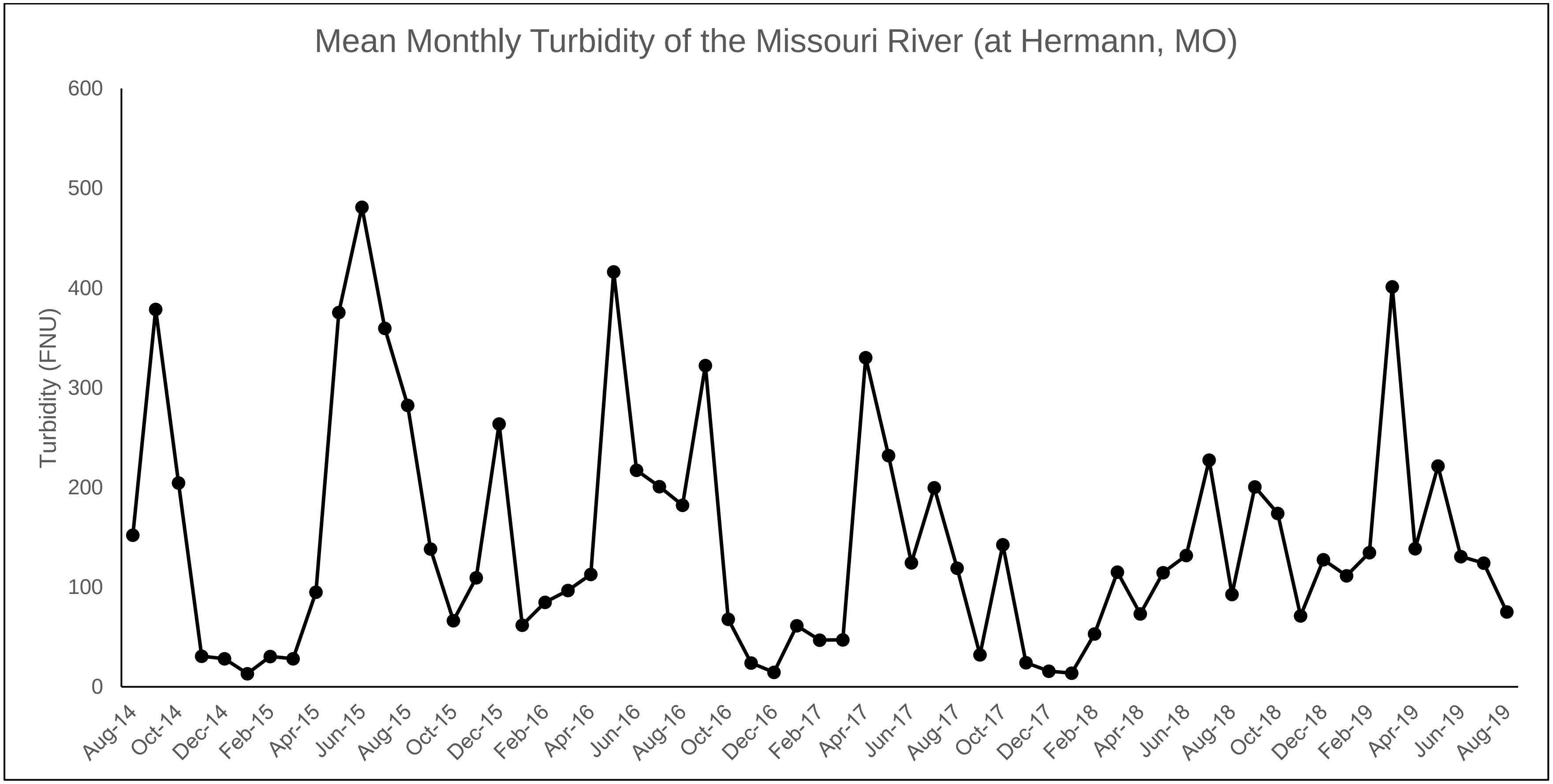

Figure 2-7. Mean Monthly Turbidity (FNU) of the Missouri River at Hermann, MO (USGS 06934500) from August 2014 through August 2019

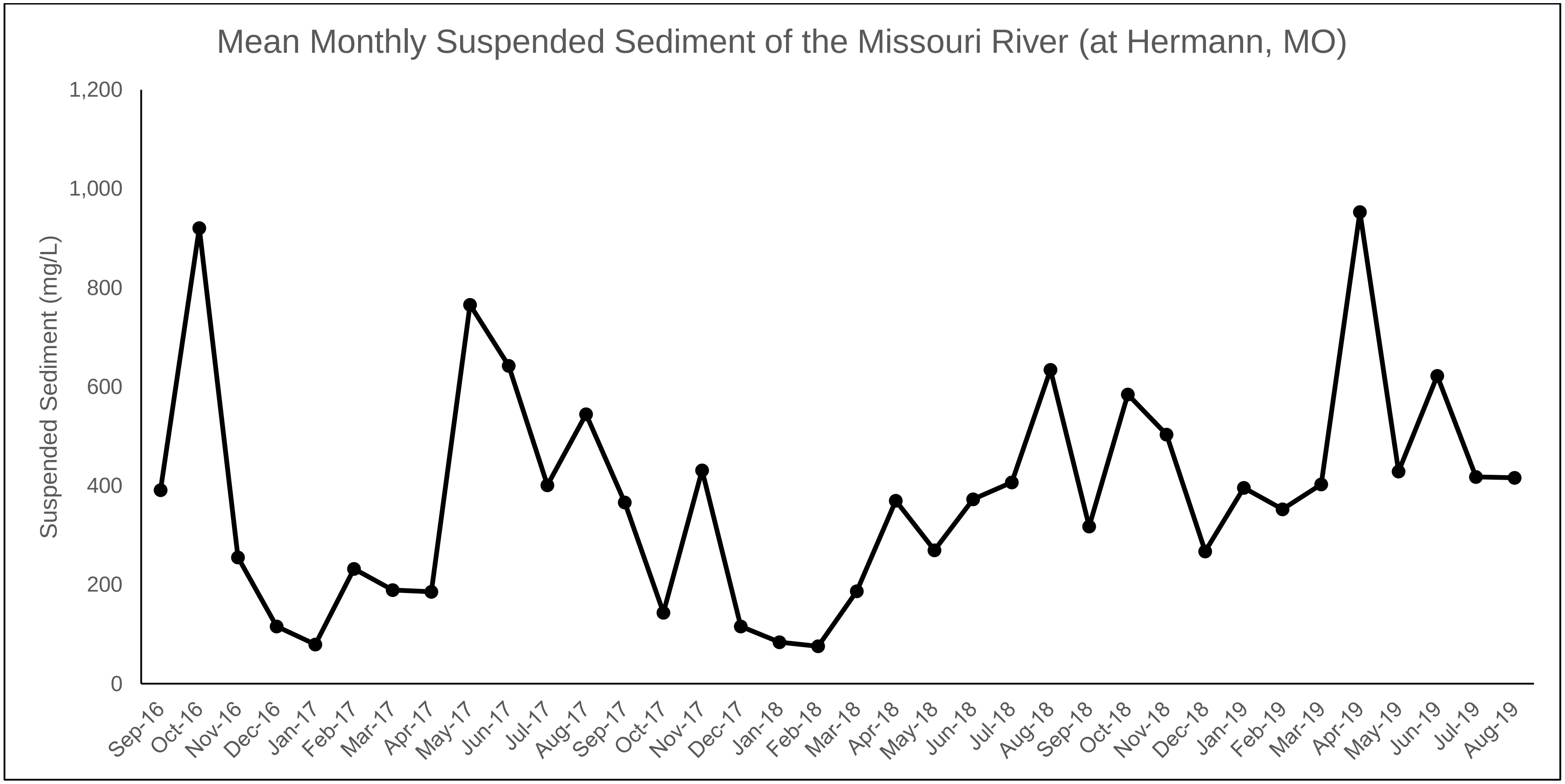

Figure 2-8. Mean Monthly Suspended Sediment (mg/L) of the Missouri River at Hermann, MO (USGS 06934500) from September 2016 through August 2019

3.0 Hydrological and Geomorphological Features

3.1 Source Waterbody Flow Characteristics

Flow characterization of the Missouri River was conducted with available discharge and stage data from the nearest stream gage to the MWIS (17.2 RM downstream) at Hermann, Missouri (USGS 06934500; 481.5 ft National Geodetic Vertical Datum (of 1929) (NGVD). Data for daily discharge were available from August 2014 through August 2019 (i.e., 5 years).

Figures 2-1 and 2-2 present the mean monthly discharge and mean monthly stage of the Missouri River at Hermann, respectively. In general, flows throughout the year can be characterized by a spring to early summer pulse, flow reduction through late summer, and low-flows in fall. Mean discharge in this section of the Missouri River during this study was 112,257 cubic feet per second (cfs) (median of 88,500 cfs) and ranged from 34,400 to 492,000 cfs. Mean stage was 12.6 ft (median of 11.1 ft) and ranged from 2.4 to 35.5 ft (483.9 to 517.0 ft NGVD). Flood stage for this section of the Missouri River is 21 ft (502.5 ft NGVD). During this five-year period, the river was above flood stage for 232 days (12.7 percent)—most recently in August of this year. Since 2014, the average river flow at the gage nearest the CEC MWIS was 60,414 million gallons per day (MGD).

The Missouri River MWIS at CEC is used to supply makeup water to the plant's closed cycle cooling system. Two intake pumps usually meet plant load requirements. CEC does not keep records of flow records for each pump. Normally, the flow is from 12,000 to 18,000 gpm (17.3 to 25.9 MGD) depending on the time of year.

3.2 Source Water Geomorphology

3.2.1 General Geomorphologic Conditions

According to 40 CFR §122.21(r)(2), geomorphologic features must also be presented as part of the physical characterization of the source waterbody. USACE Navigation charts were used to present the geomorphology (i.e., channel location and anthropogenic features) of the Missouri River at the MWIS (Figures 3-1 and 3-2).

Recent data were unavailable from USACE bathymetric surveys, so supplemental bathymetry data were estimated using in-river fisheries sampling collected in 2016 (ASA 2017). Sampling was conducted at the MWIS under various flow conditions. Water depths near the MWIS were 18 to 35 ft within the main channel, which is the dominant habitat at the intake. In summary, aquatic habitats in the vicinity of the MWIS are primarily deep with shallow areas in the littoral zone (i.e., habitats important for spawning and foraging) concentrated at the far bank at the inside bend of the river. Habitat in the main channel is uniform due to upstream wing dykes and periodic dredging to maintain a navigation channel (Figure 3-1).

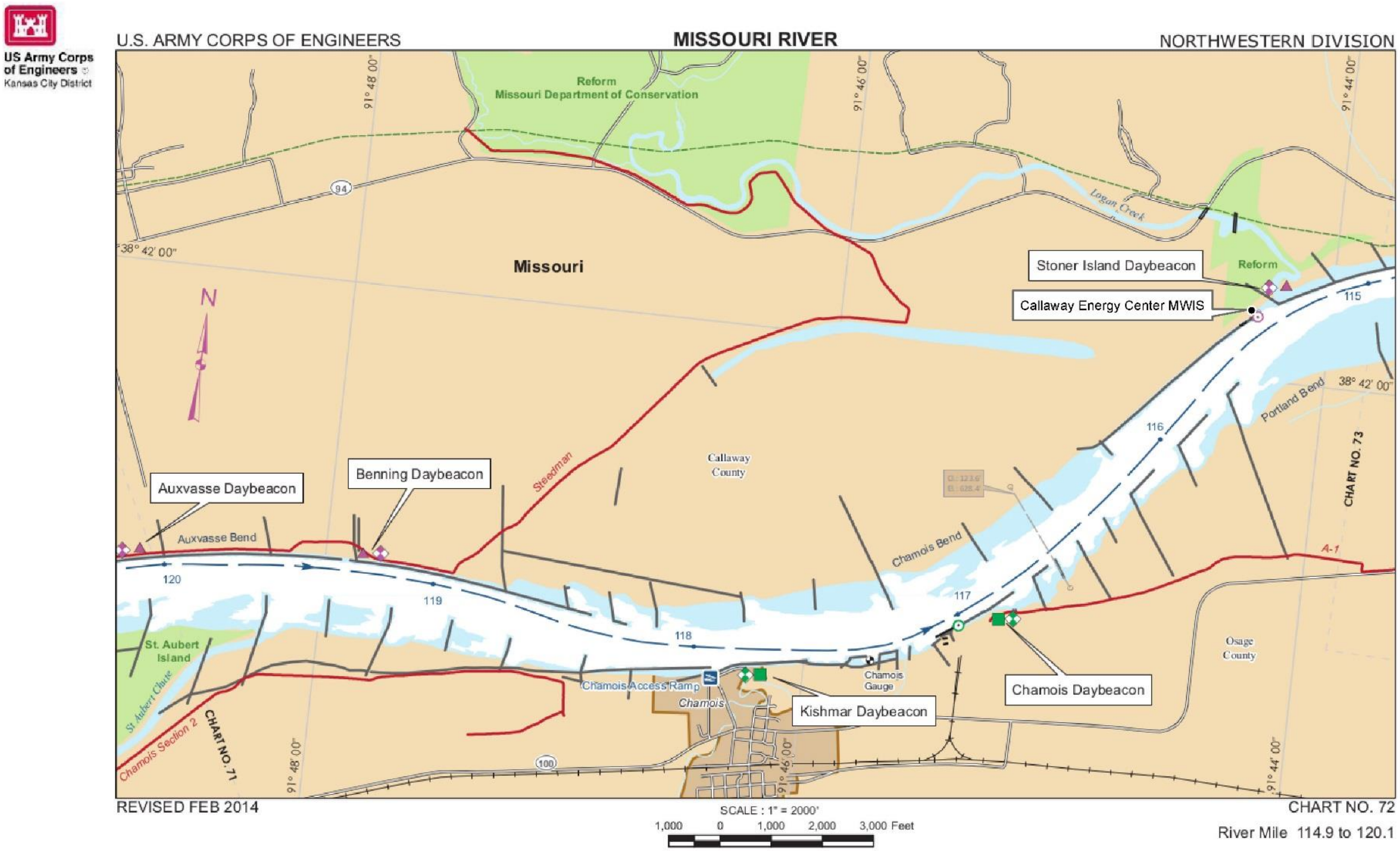

Figure 3-1. Missouri River Navigation Chart Upstream of Ameren's Callaway Energy Center MWIS

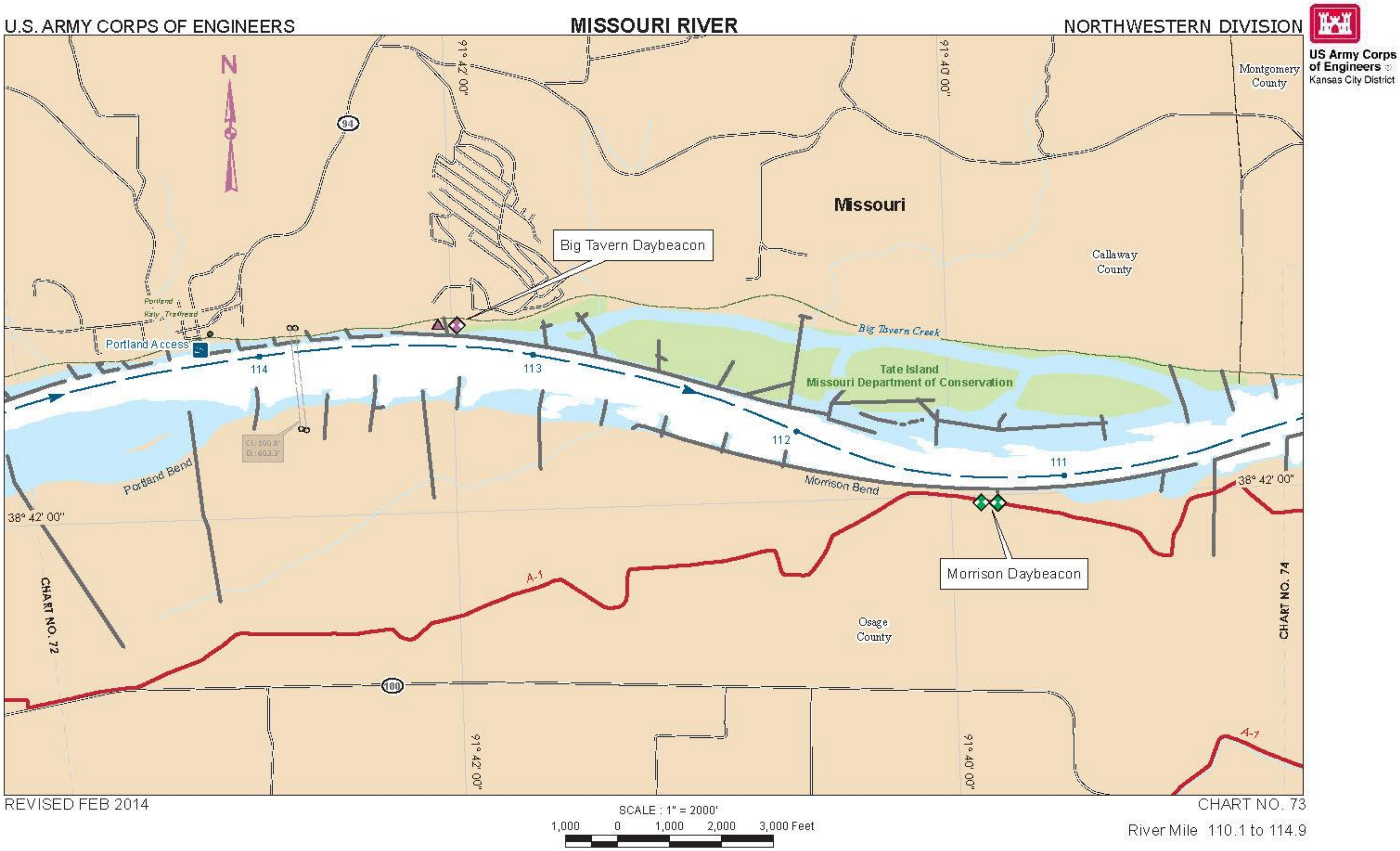

Figure 3-2. Missouri River Navigation Chart Downstream of Ameren's Callaway Energy Center MWIS

3.2.2 Area of Influence

As required by 40 CFR §122.21(r)(2), Ameren is obligated to document and characterize the area of influence (AOI) of CEC's Missouri River MWIS. The definition of AOI is site-specific and can be determined by factors such as vulnerability of aquatic organisms based on species life history, swimming speed, intake velocity, pumping rate, intake structure configuration, river stage and other local factors.

For CEC, the AOI of the Missouri River MWIS may be evaluated using the design flow velocities at multiple locations through the structure. These locations include: approach velocity at the trash rack, through velocity at the trash rack, approach velocity at the curtain wall opening, approach velocity at the traveling screen, and through velocity at the traveling screen.

3.2.2.1 Background

The CEC MWIS is a shoreline surface intake consisting of three identical pump bays with trash racks, each with a separate intake bay opening[1]. Within each bay there is a vertical three-stage centrifugal pump design-rated at 14,000 gpm. The trash racks have vertical ½-inch steel bars at 3 inches on center for an approximate percent open area of 83 percent. Stoplogs can be inserted behind the trash racks to prevent sand from migrating into the bay or can be removed to maximize intake flow. Stoplogs are typically in place during spring, summer, and fall, and are usually removed during winter when river elevations and flows are lower. The main closure gates downstream of the sand logs are 10-ft tall and 8-ft wide. Each pump bay has a standard vertical traveling screen, except each screen panel is constructed of 1/8-inch (rather than 3/8-inch) square mesh screen wire.

3.2.2.2 AOI Calculations

In order to address the requirement to determine the AOI, Ameren elected to calculate water velocities based on the design pumping capacity of the MWIS. Specifically, this approach uses existing intake design flow data, surface areas of the intakes, and source water hydrology (e.g., river stage) for calculations. The analysis consists of a numeric flow analysis to determine the velocity of water near the MWIS with the one pump operating fully. Assumptions include:

1. The velocity threshold for AOI associated with impingement is 0.5 feet per second (fps). This is the velocity threshold used by USEPA in the Rule under Compliance Option 2—0.5 fps through-screen design velocity. It is the assumed velocity that, if not exceeded, would allow a fish to escape the influence of the MWIS.
2. The approach and flow-through velocities of the MWIS were calculated using the maximum design flow.
3. A normal water level (NWL) of 502.0 ft NGVD.
4. Approach velocities were calculated at two locations:

[1] Separate intake bays theoretically have equal intake velocities (i.e., impingement risk).

   a. just upstream of the trash rack; and
   b. just upstream of the traveling screen.

5. Flow-through velocities were calculated at three locations:
   a. through the trash rack (assumed open area of 83 percent);
   b. at the curtain wall opening; and
   c. through the traveling screen (assumed open area of 73 percent).
6. Through-Screen Velocity is calculated according to the following equation:

   Through-Screen Velocity = Q/(BW*WS*CPOA)

   Where
   Q is flow rate in cfs
   BW is the screen width in feet
   WS is the screen depth from bottom of screen to the water surface elevation
   CPOA is the "calculated percent open area" of the screen

7. Calculated Percent Open Areas were:
   a. 83.3 percent for the trash rack; and
   b. 21.4 percent for travelling-water screen.

3.2.2.3 Results

Table 3-1 summarizes the input parameters, design conditions, and results of the calculations used to assess the impingement AOI (i.e., velocities > 0.5 fps). At normal water levels, only through-screen velocity at the curtain wall and travelling-water screen (i.e., 0.52 and 1.52 fps, respectively) are above the impingement velocity threshold. All other calculated velocity values are less than the 0.5 fps threshold. Therefore, under normal water levels there is no effective AOI associated with the MWIS. For those fish that enter the intake structure, fish passage gates in the side walls of each pump bay allow fish to escape at the downstream side of the intake. Each fish passage gate is normally open when the bay's intake pump is operating.

Table 3-1. Callaway's Missouri River MWIS Approach and Through-Velocity Calculations

Velocities are based on flow area at a normal water level (NWL) of 502.0 ft NGVD.			**Each Pump** (separate intake bays)
			14,000 gpm
			20 MGD
			31.2 cfs
Location	**Water Level**	**Flow Area (ft^2)**	**Velocity (fps)**
Trash Rack (approach)	NWL	101	0.31
Trash Rack (through bars)		84	0.37
Curtain Wall Opening (through)		60	0.52
Traveling Screen (approach)		96	0.32
Traveling Screen (through screen)		21	1.52
Structure dimensions and elevations:			
Trash Rack:	Top elevation: 541.0 ft; Bottom elevation: 486.0 ft; Effective height: 55.0 ft; Width: 6.4 ft; Net clean open area: 83.3%		
Curtain Wall Opening:	Top elevation: 496.0 ft; Bottom elevation: 486.0 ft; Actual height: 10 ft; Width: 6.0 ft; Open gate / stop logs		
Traveling Screen:	Top elevation: 541.0 ft; Bottom elevation: 486.0 ft; Effective height: 16.0 ft; Width: 6.0 ft; Net clean open area: 21.4%		

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